STRUCTURAL DESIGN OF A SENIOR HIGH SCHOOL BUILDING WITH SOLAR PANEL ROOFING SYSTEM IN PANGARAP HIGH SCHOOL, CALOOCAN CITY

An Experimental Research

Presented to the Faculty of Civil Engineering Division

La Concepcion College

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science in Civil Engineering

Major in Construction Engineering

and Management

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2025

RECOMMENDATION

This is to certify that this research entitled "STRUCTURAL DESIGN OF A SENIOR HIGH SCHOOL BUILDING WITH SOLAR PANNEL ROOFING SYSTEM IN PANGARAP HIGH SCHOOL, CALOOCAN CITY" prepared and submitted by John Maxwell A. Beneros, Marisad S. Galinzoga, Francinne Kaye V. Payumo, and Princess Kyla P. Riambon have been examined and PASSED the PRE-ORAL DEFENSE

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CERTIFICATE OF ORIGINALITY

This certificate hereby verifies that this was originally made by the researchers and that, to the best of our knowledge and beliefs, it does not contain any material that was previously published or written by another person nor material to which to a substantial extent has been accepted for award of any colleges and universities or other institute of higher learning, except where due acknowledgement is made thereof.

Furthermore, we declare that the intellectual content of this research is the product of our work, even though we may have received assistance from others on style, presentation and language expression.

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CHAPTER 1

The Problem and Its Background

This chapter presents the overview of the study including the introduction, background of the study, theoretical framework, conceptual framework, statement of the problem, objectives, hypothesis, scope and limitations of the study, significance of the study and definition of terms.

Introduction

In the Philippines, schools are among the most important public buildings. They serve students, teachers, and the community every day. With the increasing number of Senior High School students, new classrooms and buildings are necessary to create a safe and comfortable learning environment. In 2016, the Department of Education (DepEd) rolled out the K-12 program, which required alll public high schools to establish Senior High School (SHS) tracks. However, not all campuses could provide enough classrooms and facilities for this new educational level (DepEd, 2017). Pangarap High School in Caloocan City is one such school; despite the growing number of students, it lacks a dedicated Senior High School building.

Education in the Philippines faces many challenges, particularly regarding school facilities. One of the most essential needs for students is safe and comfortable classrooms that support effective learning. Unfortunately, many schools still deal

with a shortage of classrooms, poor facilities, and inconsistent access to electricity. Without electricity, schools cannot provide lights, fans, computers, projectors, or even charge essential devices for modern learning.

This issue is particularly evident at Pangarap High School in Caloocan City, where Senior High School is not yet exist, the schools still lack proper classrooms and the community struggles with unreliable power supply. Limited access to electricity means students often study in uncomfortable conditions, such as hot classrooms, inadequate lighting, and a lack of technology. Teachers also find it challenging to use modern teaching methods when power is inconsistent.

Background of The Study

The K–12 program has transformed the Philippine educational system by extending high school education and introducing Senior High School (Grades 11 and 12) to better prepare students for college, jobs, and entrepreneurship. While the program aims to improve education quality, its implementation has encountered significant challenges, primarily the lack of infrastructure. Studies show that many schools have struggled to build additional SHS buildings due to budget limitations, land availability, or logistics (Oracion, 2018).

At Pangarap High School, the absence of a Senior High School building creates a unique disadvantage. It is the only high school in the area without a dedicated SHS facility, even though it serves two barangays with a large student population. As a result, many Grade 10 completers must transfer to schools outside

their community. This situation increases financial pressure on families and exposes students to daily safety risks, including long commutes and traffic hazards. Santos (2021) noted that distance and travel time are significant factors contributing to student dropout rates, particularly in underserved areas.

The lack of proper facilities for different educational tracks affects the quality of learning. Areas such as STEM need science labs, TVL requires workshops, and ICT needs computer labs. Without adequate rooms, teachers struggle to deliver the curriculum, which compromises student learning.

In addition to the lacks of classrooms, an unreliable electricity supply is another major problem in Pangarap. Power outages interrupt classes and limit the use of technology in teaching. This is especially problematic for strands like ICT, which heavily rely on computers. According to Mendoza and Santos (2020), schools that integrated solar energy not only cut costs but also kept learning ongoing and raised environmental awareness among students. Similarly, the DOE (2021) promotes the use of renewable energy in public schools to lessen reliance on unstable grids and rising utility bills

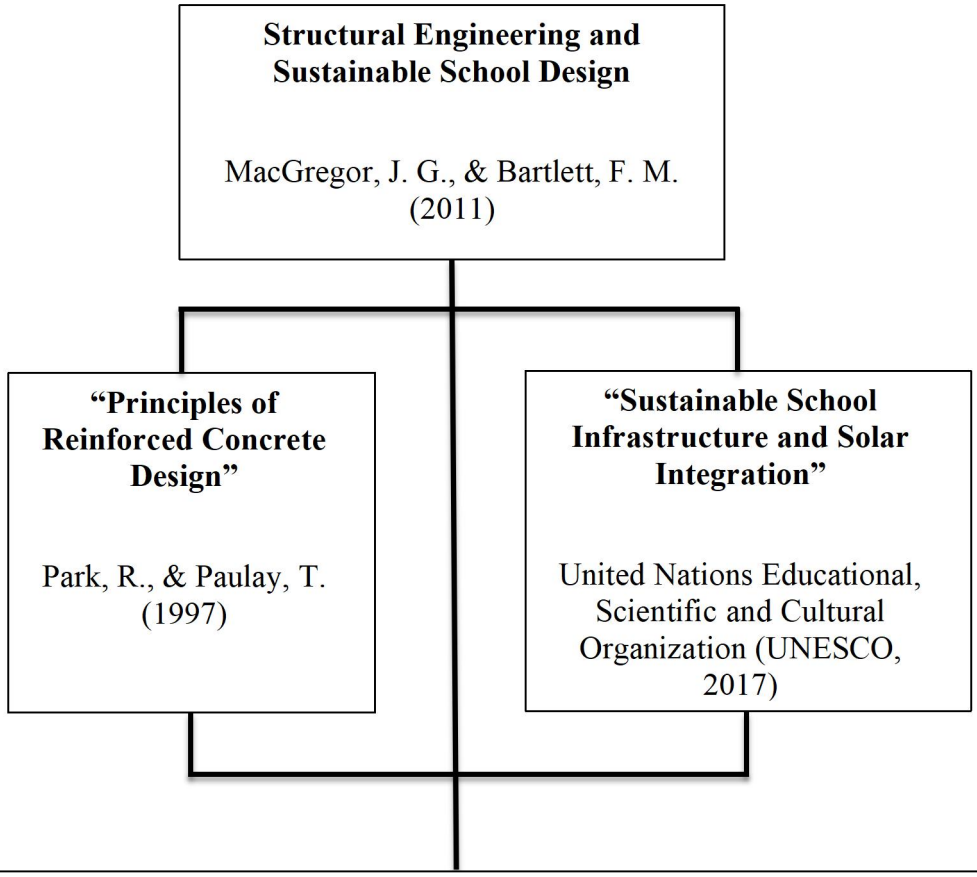
To address these challenges, the design for the first Senior High School building at Pangarap High School includes a solar panel roofing system. This building will not only provide adequate and suitable classrooms but will also incorporate a sustainable power source through solar energy. The Department of Energy (DOE, 2021) stated that solar energy is one of the most accessible and

practical renewable energy options in the Philippines, especially for schools with consistent daytime energy demands. Additionally, a study by Mendoza and Santos (2020) found that school buildings with solar panels can lower utility costs and raise environmental awareness among students.

Therefore, this project is not just about adding classrooms; it aims to addressing inequality, improve access, and ensure safety for learners. By building a Senior High School within Pangarap High School with solar panel roofing, the project meets the urgent educational and energy needs of the community. It will allow students from Pangarap and nearby barangays to continue their Senior High education locally, without the risks and burdens of traveling far. This initiative also supports national goals for sustainability, resilience, and inclusive education.

The proposed design acts as both an educational solution and a community investment. It ensures that no student in Pangarap is left behind due to a lack of facilities or electricity while serving as a model of sustainable school infrastructure that other communities can replicate in the future.

Theoretical Framework


Structural Engineering and Sustainable School Design
MacGregor, J. G., & Bartlett, F. M. (2011)
"Principles of Reinforced Concrete Design"
Park, R., & Paulay, T. (1997)
"Sustainable School Infrastructure and Solar Integration"
United Nations Educational, Scientific and Cultural Organization (UNESCO, 2017)

The theoretical framework of this study is anchored on the principles of MacGregor and Bartlett (2011) in ***Structural Engineering and Sustainable School Design***, which emphasize the importance of creating safe, stable, and code-compliant structures in line with the National Structural Code of the Philippines (NSCP, 2015). Park and Paulay (1997) further strengthen this foundation through the ***Principles of Reinforced Concrete Design***, highlighting the significance of strength, ductility, and seismic resistance to ensure the safety and reliability of multi-story school buildings.

In addition, UNESCO (2017) underscores the integration of sustainable school infrastructure and renewable energy systems, particularly solar roofing, to address electricity shortages and promote energy efficiency in underserved communities. Combining these perspectives ensures that the proposed Senior High School building design in Pangarap High School, Caloocan City is

Figure 1: *The Theoretical framework illustrates theories from different studies.*

IPO Conceptual Framework

INPUT	PROCESS	OUTPUT
1. How can the proposed structural system sustain the maximum load capacity considering dead load, live load, wind load, and seismic load in terms of: 1.1 Compliance with the National Structural Code of the Philippines (NSCP) 1.2 Stability and factor of safety of beams, columns, slabs, and foundations 1.3 Overall resistance against structural failure	● Perform structural load analysis (dead, live, wind, seismic) following NSCP standards ● Compute factor of safety of structural members ● Evaluate overall stability and resistance of the building designs.	
2. How can the durability and service life of the building materials and structural system be determined in terms of: 2.1 Resistance to deterioration under environmental exposure 2.2 Structural performance during seismic conditions 2.3 Estimated lifespan of the materials used	● Analyze material performance under local climate and environmental conditions ● Assess behavior of materials and structures during seismic events ● Estimate service life of building materials based on standards and testing	

3. How can the proposed Solar Panel Roofing system improve the sustainability and energy efficiency of the building in terms of: 3.1 Estimated solar energy generation based on available roof area and sunlight exposure on-site 3.2 Appropriate allocation of solar-powered areas based on user preference and needs 3.3 Compatibility of the solar roofing design with the existing building structure and orientation	● Estimation of solar power generation based on roof area and sunlight exposure ● Layout and load consideration of solar panels on the roof structure ● Compatibility analysis of solar panels with the roof design and building orientation	
4. How can the proposed rainwater harvesting system contribute to the sustainability and water efficiency of the building in terms of: 4.1 Estimated rainwater volume collectible based on roof area and rainfall data. 4.2 Storage tank capacity required to meet daily non-potable water demand 4.3 User perception on the acceptability and usage of harvested rainwater	● Calculation of collectible rainwater volume based on roof area and rainfall data ● Determination of storage tank capacity for daily non-potable water use ● Evaluation of user perception on system acceptance	

4. How can the allocation of usable floor areas meet the required space and strand-specific needs in terms of: 5.1 Required number of classrooms,laboratories, and faculty rooms based on DepEd standards 5.2 Minimum floor area per room according to DepEd requirements 5.3 Effective space utilization within a three-story building design	● Determine number of classrooms, laboratories, and faculty rooms based on DepEd requirements ● Verify compliance with DepEd minimum floor area standards ● Prepare architectural floor plans and layouts Of the building using AutoCAD for efficient space utilization	

Table 1**:** *The conceptual framework represents the transformation of data into output*

Statement of the Problem

The absence of a Senior High School facility in the Pangarap High School forces students to travel to distant schools, while limited access to stable electricity further hinders effective learning. To address these issues, **This study seeks to address the following research questions:**

1. How can the proposed structural system sustain the maximum load capacity considering dead load, live load, wind load, and seismic load in terms of:

    1.1 Compliance with the National Structural Code of the Philippines (NSCP)

    1.2 Stability and factor of safety of beams, columns, slabs, and foundations

    1.3 Overall resistance against structural failure

2. How can the durability and service life of the building materials and structural system be determined in terms of:

    2.1 Resistance to deterioration under environmental exposure

    2.2 Structural performance during seismic conditions

    2.3 Estimated lifespan of the materials used

3. How can the proposed Solar Panel Roofing system improve the sustainability and energy efficiency of the building in terms of:

    3.1 Estimated solar energy generation based on available roof area and sunlight exposure on-site

3.2 Appropriate allocation of solar-powered areas based on user preference and needs

3.3 Compatibility of the solar roofing design with the existing building structure and orientation

4. How can the proposed rainwater harvesting system contribute to the sustainability and water efficiency of the building in terms of:

4.1 Estimated rainwater volume collectible based on roof area and rainfall data

4.2 Storage tank capacity required to meet daily non-potable water demand

4.3 User perception on the acceptability and usage of harvested rainwater

5. How can the allocation of usable floor areas meet the required space and strand-specific needs of future users in terms of:

5.1 Required number of classrooms, laboratories, and faculty rooms based on DepEd standards

5.2 Minimum floor area per room according to DepEd requirements

5.3 Effective space utilization within a three-story building design

Objective of the Study

This study aims to develop a proposed structural design of a three-story Senior High School building with a solar panel roofing system at Pangarap High School, Caloocan City. Specifically, it seeks to achieve the following objectives:

1. To design the proposed structural system sustain the maximum load capacity considering dead load, live load, wind load, and seismic load in terms of:

    1.1 Compliance with the National Structural Code of the Philippines (NSCP)

    1.2 The stability and safety of beams, columns, slabs, and foundations

    1.3 Overall resistance to structural failure

2. To evaluate the durability and lifespan of the building materials and structural system by:

    2.1 Assessing resistance to damage from environmental exposure

    2.2 Structural performance during seismic conditions

    3.3 Estimating the lifespan of the materials used

3. To evaluate the potential of a solar panel roofing system as a sustainable energy solution for the proposed school building in terms of

    3.1 Estimating the potential solar energy that can be generated based on the available roof area and sunlight exposure on the site.

3.2 Determining the areas or facilities within the building that can be prioritized for solar energy use based on user needs and preferences.

3.3 Assessing the structural and orientation compatibility of the proposed solar roofing system for safe and efficient integration into the building design.

4. To identify how the proposed rainwater harvesting system can contribute to the sustainability and water efficiency of the building in terms of:

4.1 computing the estimated rainwater volume collectible based on roof area and local rainfall data.

4.2 determining the required storage tank capacity to supply daily non-potable water needs.

4.3 evaluating the user perception regarding the acceptability and utilization of harvested rainwater.

5. To review the allocation of usable floor areas to meet specific academic needs by:

5.1 Determining the preferred number of classrooms, laboratories, and faculty rooms through survey results and DepEd standards

5.2 Checking compliance with DepEd minimum floor area requirements

5.3 Suggesting an efficient space use plan within the three-story building design

Hypothesis

Ho: The proposed structural design of the Senior High School building with a solar panel roofing system does not significantly improve the safety, durability, and sustainability of Pangarap High School in Caloocan City.

Ha: The proposed structural design of the Senior High School building with a solar panel roofing system significantly improves the safety, durability, and sustainability of Pangarap High School in Caloocan City.

Significance of the Study

This study will be conducted to address the urgent need for a Senior High School facility in Pangarap, Caloocan City. Currently, students in the area must travel to other Schools to continue their Senior High School education. This creates safety risks, adds transportation costs, and presents accessibility challenges. The proposed building design seeks to create a safe, sustainable, and local learning environment. It also includes a solar panel roofing system to incorporate renewable energy.

For the **students**, the proposed facility will provide accessible classrooms, strand-specific laboratories, and learning spaces designed to support Senior High School tracks such as ACADEMIC and TECHPRO tracks. This ensures that learners can focus on their studies in a safe and well-equipped environment close to their homes.

For **teachers,** the design will improve working conditions. It addresses issues like overcrowded rooms and insufficient facilities. With proper faculty rooms and teaching areas, instructors can teach more effectively and guide students better.

For **the school**, the proposed design will provide a lasting solution to the lack of Senior High School infrastructure in Pangarap. By including solar energy systems, the building will lessen reliance on the unreliable community power grid and encourage sustainability. This design also optimizes land use by ensuring adequate space for all necessary academic facilities.

For **future researchers and professionals**, this study will add to the growing knowledge in structural design and sustainable school infrastructure. It will serve as a resource for future academic projects about integrating renewable energy into school facilities and designing safe, code-compliant, and cost-effective educational buildings that meet community needs.

Scopes and Limitation of the Study

This study looks at the planned structural design of a three-story Senior High School building with a solar panel roof at Pangarap High School in Caloocan City. It includes calculations of structural loads like dead, live, wind, and seismic loads according to the National Structural Code of the Philippines (NSCP). The design features beams, columns, slabs, and foundations to ensure safety and stability. The study also evaluates construction materials for durability and service life. The study focuses also on evaluating the feasibility and sustainability of integrating a solar

panel roofing system in the proposed Senior High School building based on user preferences, sunlight exposure, and roof suitability. Additionally, the study reviews the water needs of students, faculty, and staff, looking at potential sources like pipelines, deep wells, or rainwater collection. It also addresses the required space for classrooms, laboratories, and faculty rooms based on DepEd standards and the efficient use of the site in a three-story layout.

The study is limited to a conceptual structural design and does not include actual construction or implementation of the school building. No lab-based tests such as soil investigation, material sampling, or trial mixes will be conducted, as the design will depend on secondary data, standard engineering references, and published values. The solar roof will limited to survey-based data and basic estimation only, excluding detailed electrical computations, electrical layout or wiring plans and cost analysis. The water supply assessment will focus on estimating daily demand and identifying potential sources, but it will not include a complete plumbing or hydraulic design. Similarly, the durability assessment will rely on literature and standard references rather than long-term testing. Lastly, cost estimates will be preliminary and approximate, without a full Bill of Quantities (BOQ) or detailed budget breakdown.

Definition of terms

Beams- horizontal structural members carry loads from slabs and transfer them to columns.

Bill of Quantities (BOQ)- a document that lists materials, labor, and other costs needed for construction. In this study, we will only prepare preliminary cost estimates.

Classrooms- standard learning spaces for Senior High School students to receive daily academic instruction.

Columns- vertical structural members that transfer loads from beams and slabs down to the foundation.

Dead Load- the permanent weight of the building's structural parts, such as beams, columns, walls, and slabs.

Energy Sustainability- the practice of reducing reliance on outside electricity by using renewable sources like solar panels to meet the school's energy needs.

Faculty Rooms, designated work spaces for teachers to prepare lessons, check student work, and collaborate with colleagues.

Foundations- the lowest structural part of a building that transfers the overall load to the ground.

Laboratories- specialized learning facilities for strands like STEM, HUMSS, ABM, and TECHPRO tracks. These are designed for practical and hands-on learning.

Load Analysis- the process of calculating forces (dead load, live load, wind load, seismic load) acting on the structure to ensure safety and meet design standards.

Live Load- temporary or movable loads on a structure, including people, furniture, and equipment.

National Structural Code of the Philippines (NSCP)- the building code in the Philippines that sets safety standards for design and construction to ensure stability and resistance to natural hazards.

Natural Hazards- environmental forces such as earthquakes, typhoons, or floods that can affect the safety and durability of a building.

Service Life- the expected duration that the school building can function well before major repairs or replacement are needed.

Slabs- flat structural elements that create the floors and ceilings of the building.

Solar Panel Roofing System- a roof-integrated renewable energy system that collects solar energy and provides electricity to the school building.

Structural Stability- the building's ability to hold up under loads without collapsing or deforming excessively.

Sustainability in Education- the integration of eco-friendly and energy-saving practices in schools to encourage long-term learning and environmental responsibility.

Wind Load- the pressure that wind exerts on a structure, which the design must counteract

CHAPTER 2

Review of Related Literature and Studies

This chapter represents a review of related literature and studies, following a through search done by local and foreign researchers.Those included in this chapter and in familiarizing with relevant and related information to the current study.

Foreign Literature

According to Ravelo-García et al. (2025) developed a hybrid approach integrating neuro-fuzzy inference systems and structural reliability analysis to evaluate the remaining service life (RSL) of reinforced concrete buildings. Based on field investigation of 21 RC buildings, the study uses an adaptive neuro-fuzzy inference system (ANFIS) combined with structural reliability theory to model combined deterioration (carbonation, cracking, strength loss, etc.). It estimates the remaining service life (RSL) of structural members and identifies which structural parts are more vulnerable. This kind of multi-factor modeling is helpful for your proposed building in determining which elements (roof framing, columns, beams) might degrade faster and hence require more durable design upfront. The results indicate that intelligent modeling tools can significantly improve predictive accuracy for structural degradation, allowing better long-term maintenance planning.

According to Iturralde-Carrera et al., (2025), a systematic review was carried out of 122 recent articles (2018-2025) that address mounting support structures for

PV systems. The review categorizes materials (mild steel, galvanized steel, aluminum, polymers, composites) and structural design attributes (tilt angle, orientation, support typology, load types, environmental adaptation). The authors concluded that matching structural design to the specific climatic conditions—such as wind, seismic exposure, and corrosion risk—significantly enhances both service life and performance of PV systems. For the design of the senior high school solar roofing, this provides concrete guidance on selecting appropriate support materials, detailing wind and load resistance, and anticipating long-term environmental effects.

According to Yin, Li & Han, (2024), an overview of how solar roofing contributes to energy savings, discussing not only electrical generation but also structural, thermal, and environmental impacts. They highlight that the added dead loads of panels, dynamic loads from wind/snow (where applicable), and long-term degradation of both module and mounting structure must be considered in early design phases. This comprehensive perspective offers valuable insights for integrating solar panel roofing structurally into school building design.

According to Hossain et al. (2021) provides valuable insights into the state of water supply systems in educational institutions located in challenging environmental conditions. Conducted in coastal regions of Bangladesh, the research revealed that rainwater harvesting (RWH) was the most common source of drinking water, used by 63% of the surveyed schools. In contrast, pond water (21%) and tube wells (16%) served as supplementary water sources. It emphasized that the

continuity of water availability was heavily influenced by seasonal rainfall patterns, leading to shortages during dry months when stored rainwater was depleted. The study also assessed the infrastructure characteristics of schools, such as the suitability of roofing materials for rainwater collection and the adequacy of storage tanks, noting that poor design and maintenance often compromised water quality and system efficiency.

According to Andrade et al. (2024) analyzed data from Ecuadorian schools and found a statistically significant correlation between the quality of classrooms, laboratories, libraries, and student outcomes. They argue that aspects like ventilation, daylighting, acoustics, and structural layout play a crucial role in enabling effective teaching and learning, and that poor facility conditions can hinder educational performance. This underscores that structural design must go beyond mere load capacity to account for human comfort and adaptability in school infrastructure.

Local Literature

According to DepEd (2022), the introduction of vertical school designs serves as a strategic solution to the growing problem of limited land availability in urban areas. The DepEd emphasized that constructing medium- to high-rise school buildings can maximize constrained spaces and help accommodate the increasing number of senior high school students in highly populated cities such as Manila and Caloocan. This design approach responds to the demand for additional classrooms without requiring extensive land acquisition, which is often difficult and costly in

urban communities. Furthermore, the innovation reflects the government's broader shift toward modernized and sustainable educational infrastructure that prioritizes spatial efficiency, safety, and environmental responsibility. By integrating vertical design principles with resilient structural features, the Department of Education aims to promote a learning environment that is both functional and adaptive to future urban development needs.

Navarro (2024) from the Philippine Institute for Development pointed out the ongoing challenges in achieving fair and sufficient school infrastructure in the Philippines. Despite progress in building new classrooms, many schools, especially in rural and coastal areas, still deal with overcrowding, poor sanitation, and a lack of learning facilities. These issues affect the quality of education and put student safety at risk. The study also observed that infrastructure development is uneven, with urban schools getting more resources than those in remote areas. Navarro concluded that equal investment, better project execution, and strict compliance with national construction and safety standards are crucial for improving educational facilities across the country.

Ambubuyog et al. (2024–2025) they looked at how the quality of school facilities influences student participation and academic engagement. The researchers found that students rated their school facilities as only moderately adequate due to overcrowding, poor ventilation, and lack of lab equipment. However, the study also noted that well-maintained facilities led to higher student motivation and

engagement. The researchers stressed that improving school infrastructure greatly contributes to better learning results and supports the K–12 program's goal of quality education.

According to Ramos and Gonzales (2024) studied the way on how he can install solar panels using the grid tied rooftop solar PV system for public elementary school in Laguna, Philippines by using software called HOMER pro to check if this is cost effective and beneficial for the school. This study focus at the system's cost, the energy that can produce, and how much money the school can save on their electricity cost. This study by using solar panels can help to reduce the electricity cost and support clean energy use. It's still connected to the grid in case that the energy produce by the solar panels are not enough. The study highlights that solar panel roofing system is need to have proper planning and design because solar panels is a good idea for public schools in the Philippines.

According to both Makati City and Imus City have successfully deployed solar panel systems across multiple school buildings to lower electricity expenses and promote environmental awareness among students (Makati LGU, 2023; DepEd–Imus, 2020) successful solar panel projects in several schools, reducing electricity bills and raising environmental awareness among students. These initiatives show how collaboration between DepEd, local governments, and private entities can improve school sustainability. The projects typically involved tailored solar setups based on each school's energy needs, ranging from small classroom kits to larger

multi-kilowatt systems. Moreover, these programs connected renewable energy use with educational goals by enhancing digital learning, supporting device usage, and encouraging environmental responsibility among students.

Foreign Study

Kahrizi and TahamouliRoudsari (2020), in this study they evaluated the durability of educational buildings during a major seismic event. This research explored the impact of the damage that can cause to the school facilities and determined the main factors that added the possibilities to the vulnerability of the building including the substandard construction practices and inadequate seismic provisions. The highlight of this study is the importance to meet the standard of the building codes, regular structure inspection, and structural improvement programs especially those buildings that are located to areas that are prone to earthquakes. This study is really important for disaster risk reduction planning and ensuring the safety and resilience of education systems despite natural calamities.

According to the study "Durability and Climate Change—Implications for Service Life Prediction and the Maintainability of Buildings" by Lacasse, Gaur, and Moore (2020), the importance of incorporating climate projections ensures the maintenance planning and building resilience accurately. It highlighted that excessive exposure to extreme weather events, sudden change in temperature, and moisture can quicken the deterioration of the materials, affecting structural integrity significantly and increasing cost of maintenance. Their findings emphasize the

require of adaptive building designs and materials that can resist future environmental concerns, recognizing this study to be highly relevant to sustainable construction and infrastructure planning.

Abdillah et al. (2023) explain how solar power systems can be used in public schools in Indonesia. Their studies focused on designing systems that can help to reduce the cost of electricity and rely more on clean energy. The researchers discover the most effective and reliable for the school which is the hybrid systems where solar energy combined with electricity from the power grid. This system not only reduced the electricity cost but also provide sustainable and environmental friendly energy resources for schools. The researchers propose that using solar energy in schools has a big impact to the power resources that the education facilities needs for the school.

In the study “Calculating Rain Water Harvesting for a Building” by C. Babu, et al. (2025), the researchers analyzed the potential of rainwater harvesting (RWH) as a sustainable approach for reducing dependence on conventional water sources. The study presented a quantitative method for estimating the amount of rainwater that can be collected based on rooftop area, annual rainfall, and runoff efficiency. The researchers outlined a standard formula that considers key factors such as surface type and local climatic conditions to determine the harvesting potential accurately. Furthermore, the study discussed the multiple benefits of implementing RWH systems, including groundwater recharge, flood control, and long-term cost savings. The authors emphasized that efficient design of storage and filtration

systems is essential to maximize water usability and system performance. Overall, the study demonstrated that incorporating rainwater harvesting in both urban and rural building designs contributes significantly to sustainable water management and environmental conservation.

AKahrizi and TahamouliRoudsari (2020), in this study they evaluated the durability of educational buildings during a major seismic event. This research explored the impact of the damage that can cause to the school facilities and determined the main factors that added the possibilities to the vulnerability of the building including the substandard construction practices and inadequate seismic provisions. The highlight of this study is the importance to meet the standard of the building codes, regular structure inspection, and structural improvement programs especially those buildings that are located to areas that are prone to earthquakes. This study is really important for disaster risk reduction planning and ensuring the safety and resilience of education systems despite natural calamities.

Local Study

Del Rosario, M., Santos, R., and Alonzo, P. (2022) conducted t a study called "Structural Performance Assessment of Reinforced Concrete School Buildings Based on the National Structural Code of the Philippines (NSCP 2015)" at the Polytechnic University of the Philippines. The research evaluated the stability and safety of three-story school buildings under dead, live, wind, and seismic loads using STAAD Pro for structural analysis. The results indicated that buildings following

NSCP load combinations and detailing requirements had greater load resistance and stability during simulated earthquakes. The researchers pointed out that following the code, proper reinforcement detailing, and accurate load estimation are crucial to preventing structural failures. This supports the current study's goal to design a code-compliant Senior High School building at Pangarap High School that can safely handle maximum loads.

Lee et al. (2021), in their study "Assessment of Building Material Performance in Humid Climates," examined how moisture, temperature changes, and long-term humidity affect the strength and durability of materials such as concrete, steel, and composites. Conducted in several tropical regions, the study found that high humidity speeds up steel corrosion, creates microcracks in concrete, and weakens composite adhesion. The researchers emphasized that using moisture-resistant materials, corrosion inhibitors, and proper ventilation can reduce structural damage and maintenance costs. These findings highlight the importance of choosing materials that suit the climate and using preventive design measures, especially in tropical countries like the Philippines, where humidity and rainfall significantly shorten building lifespan.

According to Busaña (2021), the use of a hybrid solar energy system at Mindanao State University of Sulu found that the teachers and students preferred this kind of system compare to the regular power supply that they use because it helped to reduce the electricity costs. The system was designed to provide more stable and

low cost power supply by combining solar energy with traditional main supply of electricity. The staff believed that it helps to improve the quality of services on their institution. The system was expensive to install, but it became more cost effective after several years because electricity are more reliable and improve the daily performance of the staff and teachers.

Dela Cruz and Santos (2021) looked into the feasibility of rainwater harvesting (RWH) systems in rural public schools in Cavite as an alternative water source for sanitation. Their study focused on roof catchment design, storage capacity, and daily water demand. The results showed that a well-designed RWH system could supply up to 60% of a school's daily water needs for handwashing, cleaning, and toilet flushing. The researchers highlighted that system efficiency relies on roof area, rainfall patterns, and regular maintenance. They noted that adding filtration and disinfection can improve water quality. The study concluded that RWH systems offer a cost-effective and sustainable solution for schools dealing with water shortages.

According to Navarro (2022), the condition of school infrastructure in the Philippines continue to face significant issues such as overcrowded classrooms, poorly maintained buildings, and insufficient essential learning facilities. This study highlights that lack of infrastructures in public schools not only affects the physical environment of students but also have a big impacts in the motivation and attendance of the student and to their learning experience. It is also emphasizes that simply

increasing the number of classrooms is not enough, the student also need a sustainable and well-planned infrastructure to ensure the safeness of the students and the long term function of the building. He also wants to consider the developing of needs in education, such as integrating technology and creating flexible learning spaces since in these days the technology keeps evolving and changing.

Synthesis of Review in Related Literature and Studies

Both foreign and local literature emphasize that the overall performance and sustainability of educational buildings rely on multiple engineering and architectural factors, including structural stability, energy efficiency, water resource management, and spatial functionality. Andrade et al. (2024) and Rashid (2021) noted that the physical condition of classrooms, laboratories, and other school facilities directly influences learning outcomes. Meanwhile, Ravelo-García et al. (2025) and Kahrizi & TahamouliRoudsari (2020) found that adding reliability analysis and seismic measures improves building resilience and service life. Research on photovoltaic (PV) systems by Iturralde-Carrera et al. (2025), Yin et al. (2024), and Abdillah et al. (2023) highlighted the importance of considering structural loads, climate adaptation, and long-term degradation in the design of solar roofing for schools. Hossain et al. (2021) provided valuable insights on water management through rainwater harvesting and the importance of infrastructure design for ensuring a clean and continuous water supply. Together, these international studies underline the need for a design process that combines structural integrity, environmental conditions, and building sustainability.

Local studies support these findings but focus on specific challenges in the Philippines. DepEd (2022) and Navarro (2024) discussed the need for vertical school designs to maximize limited urban spaces and enhance safety. Dela Cruz and Santos (2021) found that properly designed rainwater harvesting systems in rural schools can supply a significant portion of daily water needs for sanitation and hygiene, emphasizing that such systems are cost-effective and sustainable when regularly maintained. Busaña (2021), Ramos & Gonzales (2024), and local government initiatives in Makati and Imus show how renewable energy systems like solar panels can lower electricity costs and promote sustainability in schools. Additionally, Trinidad (2020) and Navarro (2022) emphasized that improved infrastructure directly benefits the learning environment and student performance. study's goal to propose a structurally sound, sustainable, and student-centered Senior High School building that promotes both safety and quality education, and support long term use.

CHAPTER 3

Research Methodology

This chapter presents the research methods, procedures, and analytical techniques used to systematically address the objectives of the study. It discusses the research design, respondents, sampling method, research instruments, data-gathering procedure, and statistical treatment used for interpretation and validation.

Research Design

The study uses a Descriptive Quantitative Research Design to collect and statistically analyze numerical data from student and faculty respondents. This method aims to find patterns and trends related to water consumption, electricity use, and awareness of sustainability. The research combines engineering design principles with sustainability assessment to propose a three-story Senior High School building featuring solar power and rainwater harvesting system as an alternative water source. The data collected from respondents are analyzed to support the inclusion of design features that promote efficiency, safety, and environmental sustainability.

Design Process

Conceptualization

The proposed design follows the National Structural Code of the Philippines (NSCP), and other relevant local and international standards. These codes ensure the safety, stability, durability, and compliance of the building and its utilities. The concept emphasizes sustainability by using solar energy systems for power supply and implementing rainwater harvesting for water efficiency.

Site Analysis

The site for the proposed Senior High School building is evaluated based on space availability, topography, accessibility, existing water and power connections, and environmental impact. The analysis ensures the building layout supports the daily flow of students and provides areas suitable for sustainable installations like solar panels and proposed rainwater harvesting system.

User Needs

The design addresses the needs of students, teachers, and school administrators. Facilities are planned to meet academic, technical, and comfort needs, including classrooms, laboratories, and restrooms. Survey results on the proposed rainwater harvesting system, comfort levels, and energy use patterns were used to guide the inclusion of appropriate systems that promote efficiency and safety.

Design Tools and Software

1. **AutoCAD** for architectural layouts like 2D and Elevation design.

2. **SketchUp** for 3D visualization and presentation of the design.

3. **Excel** for tabulating survey data and calculating water demand estimates.

4. **STAAD Pro / SAP2000** for structural and load analysis.

Sample and Population

The study looks at Senior High School students, faculty members, and administrators at Pangarap High School. These groups are the main users of the proposed building and share their thoughts on their needs, comfort, and knowledge of sustainable facilities. Their feedback helps shape decisions about classroom space, the practicality of water systems such as rainwater harvesting, and energy efficiency.

Sampling Technique

This study uses a purposive sampling method. Respondents are chosen for their relevance to the proposed project, including students and faculty who will use the facility regularly. This ensures that the gathered data reflects user needs and sustainability priorities.

Research Instrument

In this study, we use several tools to gather the data needed for designing and evaluating the proposed Three-Story Senior High School Building.

A. Designing

We create 2D and 3D models to show the layouts and visualizations of the proposed structure. AutoCAD helps us make floor plans, elevations, and sections. SketchUp allows us to produce 3D models that visualize the spatial layouts, room connections, and overall architectural design. These design tools ensure that the proposed building meets the DepEd standards for Senior High School facilities and follows the National Building Code of the Philippines (NBCP).

B. Survey Questionnaire

We distribute structured questionnaires to selected incoming Senior High School students at Pangarap High School. The survey aims to gather data about water usage, electricity concerns, space sufficiency, and safety conditions. Specifically, it collects:

a. Daily school attendance and water-use habits for estimating total water demand.

b. Student opinions and needs on sustainable features like solar panels

c. Students and Teachers feedback on how many strand will be prioritized first in the first proposed building

C. Structural Analysis Software (STAAD & SAP2000)

We use structural analysis software to assess the strength, stability, and load-bearing capacity of the building. These tools simulate the effects of dead load, live load, wind load, and seismic load in line with the National Structural Code of the

Philippines (NSCP). The analysis guarantees that the structural design offers adequate safety, stability, and serviceability against potential failures.

Data Gathering

The data collection for this study followed several systematic steps to ensure the results were accurate and reliable. First, the validated questionnaires were given to selected Senior High School students, teachers, and administrators who participated in the study. The responses from the participants were collected, inputted, and organized using Microsoft Excel for proper tabulation and statistical analysis. The analyzed data were used to back up the validation of the proposed architectural and engineering designs, with a focus on developing the water source system and adding solar panel energy into the building.

Then after Data collection, the Structural Design work will start thorough review of relevant standards and references, including the National Structural Code of the Philippines (NSCP), Department of Education (DepEd) facility requirements, and literature on solar energy integration, and sustainable school design. A site visit was conducted to obtain actual field measurements, assess lot boundaries, and evaluate terrain conditions. This helped determine suitable locations for the solar panel and and evaluate the feasibility of a rainwater harvesting system as a potential water source for the building.Measurements were taken with standard engineering tools, and photographs and field notes documented the process.

The next phase involved design calculations and simulations using AutoCAD for drafting, STAAD Pro for structural load analysis, and Environmental data such as solar irradiance and rainfall averages were collected from PAGASA and DOE databases to improve accuracy. Through these methodologies, the study aims to ensure that the proposed Senior High School building design is structurally sound, environmentally sustainable, and functionally suitable for educational use.

Statistical Tools

The statistical tools used in this study include Percentage and Frequency Distribution, which summarize the demographic characteristics of respondents; Weighted Mean, which gauges the overall perception and level of agreement on different indicators; and, when needed, the Chi-Square Test, which checks for significant relationships between categorical variables such as gender, frequency of use, and water consumption behavior. These tools together help interpret survey data clearly and support the reasoning behind the proposed design and system solutions.

Percentage and Frequency Distribution

Used to describe the demographic characteristics of the respondents such as strand, gender, and year level.

$$\textbf{Percentage} = \frac{f}{N} \times 100$$

Where:
f = frequency of each response
N = total number of respondents

Weighted Mean

Used to determine the average perception or agreement level for each survey item.

$$\bar{x} = \frac{\sum fx}{n}$$

Where:
f = frequency of responses
w = weight assigned to the response
N = total responses

Likert Scale Interpretation

The data we gather will support our assumptions and design parameters for the water supply system, solar energy installation, and space allocation of the proposed building for using a Likert Scale Interpretation.

Scale	Verbal Interpretation	Range
5	Strongly Agree	4.20 – 5.00
4	Agree	3.40 – 4.19
3	Neutral	2.60 – 3.39
2	Disagree	1.80 – 2.59
1	Strongly Disagree	1.00 – 1.79